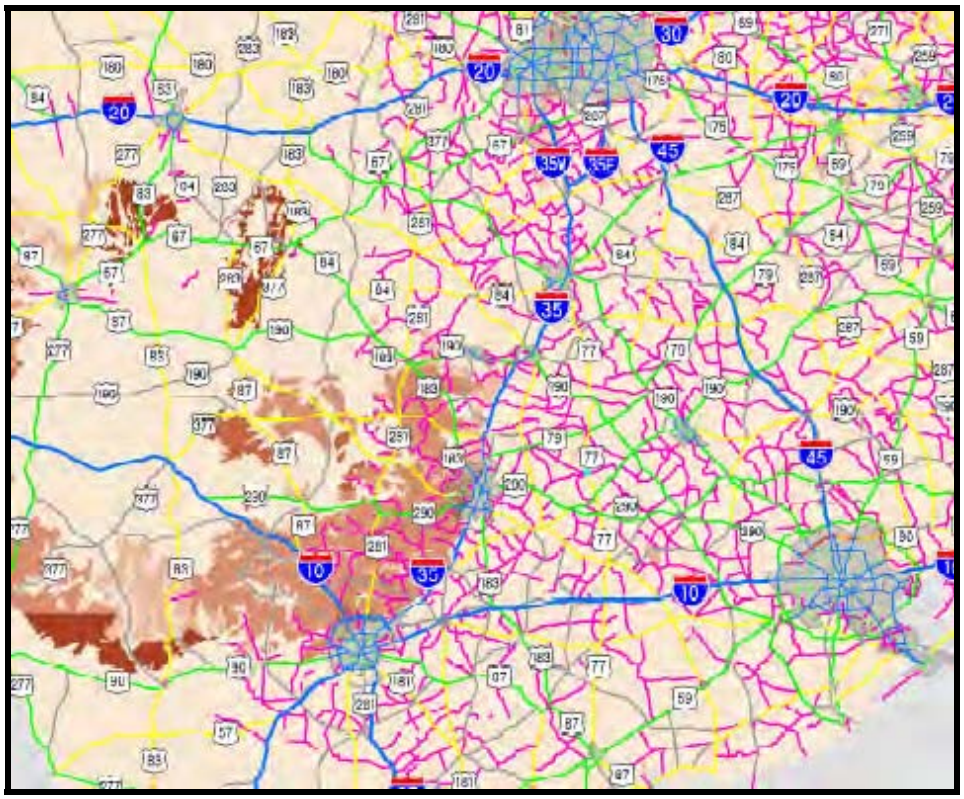
APPENDIX C

DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

Roadside Pest Management Program
Final Water Quality Runoff Assessment



Prepared for:

Texas Department of Transportation

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1.0 INTRODUCTION

This water quality modeling report is presented as a part of the Texas Department of Transportation's (TxDOT) effort to supplement its Final Environmental Impact Statement (FEIS) for the Roadside Pest Management Program. An initial EIS was completed in 1996 and since that time, new techniques, chemicals, and procedures have become available. A supplement is necessary in order to fully disclose and inform the public on the environmental impacts of the Pest Management Program and to adhere to the State of Texas' rules.

1.1 OBJECTIVE

Within the overall context of this updated Supplemental EIS (SEIS), the purpose of this water quality modeling report is to present the methods, model inputs and assumptions, and results from this effort in order to assess the effect on Texas water quality of the chemicals currently in use or proposed for use by TxDOT in its Roadside Pest Management Program. This report is complemented by an ArcGIS 9.0 project to be used by TxDOT professionals in their day-to-day operations and/or policymaking discussions. This report and combined ArcGIS project will facilitate environmentally sensitive decision making, which supports the mission of TxDOT. TxDOT Maintenance Division (MNT) maintains the ArcGIS project on file at its office in Austin, Texas.

The first objective of the modeling effort was to determine the runoff and leaching potential of the various chemicals used or planned for future use in the program. This evaluation was completed through modeling. The model output provided a comparative evaluation of the chemicals and their loss in runoff and/or groundwater leaching based on the different soils types found in Texas. The model also estimated concentrations of chemicals in runoff and groundwater by considering a number of variables, including regional climate conditions, soil types, chemical application rates, chemical properties, etc.

1.2 ASSESSING WATER QUALITY

Ideally, chemicals applied to roadside vegetation would remain in the root zone or on the plant until they degraded. Some fraction of applied chemicals move from target areas into the surrounding environment through three pathways: 1) dissolution in runoff water; 2) percolation out of the root zone into groundwater; and 3) adsorption to

soil particles. The modeling effort conducted for this report provides estimates of the quantity and concentration of chemicals potentially entering the environment via surface water runoff or the percolation of chemicals into groundwater.

1.2.1 Surface Water

Within Texas there are approximately 191,228 river and stream miles, of which 40,194 miles are perennial streams. There are 23 defined major river and coastal basins in Texas. The major river basins consist of the drainage areas for Texas' 15 major rivers. In many cases, other named streams are tributaries of these major rivers. The coastal basins are those drainage areas located between major stream drainages on the coast. These areas drain to the Gulf of Mexico through small rivers and streams that discharge directly to the Gulf or its bays.

Most water that would enter streams or aquifers from a TxDOT right-of-way (ROW) would do so via storm water runoff. Storm water runoff occurs because of precipitation. Any water not absorbed by soil becomes storm water runoff. This runoff flows over the ground surface downhill until it enters some type of surface water feature. Hard, impervious surfaces such as concrete and asphalt increase runoff because they act as a barrier between soils and precipitation. As a result, the construction of transportation facilities increases the volume storm water runoff. Storm water runoff associated with transportation facilities is usually collected, treated, and discharged into nearby surface water bodies.

In spite of storm water collection and treatment measures, some chemical loading in transportation facility storm water runoff and nearby surface water bodies can and does occur. From the perspective of the Pest Management Program, chemical loading into storm water runoff and surface waters can occur when: 1) chemicals wash off of target areas during precipitation events; 2) chemicals are applied directly to a surface water bodies as a result of overspray or intentional application; 3) chemicals are accidentally spilled into a surface water body within the ROW; or 4) treated vegetation containing chemical residues enters into surface water bodies.

1.2.2 Groundwater

Water is found in the unsaturated and the saturated zones beneath the ground surface. The unsaturated zone lies directly underneath the land surface where air and water particles fill the spaces between soil and rock particles. The saturated zone does not

contain much air in its pores and typically lies beneath the unsaturated zone. The term groundwater applies to the saturated zone. Surface water recharges groundwater by percolating through the unsaturated zone.

In Texas, there are nine major aquifers and 20 minor aquifers. Water that does not runoff as storm water infiltrates into the soil. Most of the aquifers of Texas are recharged by infiltration of precipitation into soil and then into the underlying geological formation containing the aquifer. Other shallow alluvial aquifers associated with streams in Texas are present as well as the major and minor aquifers previously listed.

Chemical loading into groundwater can occur when: 1) chemicals are washed off the plants into the upper layer of soil (i.e., unsaturated zone); or 2) chemicals are spilled on to the ground surface and then slowly move downward through soils into the groundwater.

1.3 CHEMICALS STUDIED

For purposes of the SEIS and this Water Quality Runoff Risk Assessment, 11 chemicals (i.e., active ingredients of various pesticide products) were evaluated. These chemicals include:

1. Glyphosate (Roundup Pro, Roundup Original Max, and Aquamaster)
2. Sulfometuron methyl (Oust XP)
3. Sulfosulfuron (Outrider)
4. Metsulfuron methyl (Escort XP)
5. Fluroxypyr (Vista)
6. Triclopyr (Garlon 3a)
7. Clopyralid (Transline)
8. Blend of chlorsulfuron and sulfometuron methyl (Landmark MP)
9. Amino pyralid (Milestone VM)
10. Imazapyr (Habitat)
11. Fenoxycarb (Award)

A variety of sources was reviewed in order to obtain information about these chemicals. These sources included databases available on the Internet, manufacturers' labels, material safety and data sheets (MSDS), risk assessment reports available from

the United States Forest Service (USFS), and personal communication with the manufacturers.

1.4 ORGANIZATION OF REPORT

This report is organized into four sections, including this introduction. Section 2.0 contains descriptions of the model(s) used to evaluate potential water quality changes. Section 3.0 contains the results of the modeling effort, summary and conclusions are provided in Section 4.0, and references in Section 5.0.

2.0 MODEL DESCRIPTION

2.1 NAPRA GLEAMS APPLICATION

The GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) model Version 3.0 is a computer program used to simulate water quality events on an agricultural field. GLEAMS, a nonpoint source model, was developed by Knisel and Davis (2000) to evaluate the impact of management practices on potential pesticide and nutrient leaching within, through, and to the bottom of the root zone. The model also estimates runoff and sediment losses from the field (i.e., erosion). It was developed as a tool for the comparative analysis of complex pesticide chemistry, soil properties, and climate, but not as an absolute predictor of pollutant loading (Leonard, Davis, and Knisel, 2002). GLEAMS was used in the original version of the SEIS and was proposed for use in this work in order to provide continuity in the SEIS and to extend its usage to new chemicals.

The GLEAMS Version 3.0 model is downloadable from a website hosted by the United States Department of Agriculture (USDA) Southeast Watershed Research Laboratory (USDA-ARS Southeast Watershed Research Library, 2004). However, due to the wide range of soils in Texas, a web-based application of GLEAMS, called NAPRA WWW (National Agricultural Pesticide Risk Analysis, World Wide Web), was used to evaluate the potential effects of chemical loading in runoff and groundwater. NAPRA WWW is included in the National Resource Conservation Service (NRCS) policy and requirements for pest management (NRCS, 2001) and is used by NRCS specialists and their technology partners.

According to the article, "Extension and Enhancement of National Agricultural Pesticide Risk Analysis (NAPRA) WWW Decision Support System to Include Nutrients" by Lim and Engel (2003):

> The NAPRA WWW system uses GLEAMS as a core model to simulate hydrology, erosion, pesticide, and nutrient losses. The pre-processor in the NAPRA WWW system constructs the GLEAMS input files from the user provided crop management, pesticide, and nutrient data in the input interface, by querying databases and by running weather generator models. The GLEAMS hydrologic/water quality model within the NAPRA WWW system requires numerous soil properties, crop

> management information for the area of interest, long-term daily temperature and precipitation data, tillage practice data, pesticide properties, and nutrient properties…The STATSGO soil data for the continental US was added to the original NAPRA database to extend NAPRA nationwide.

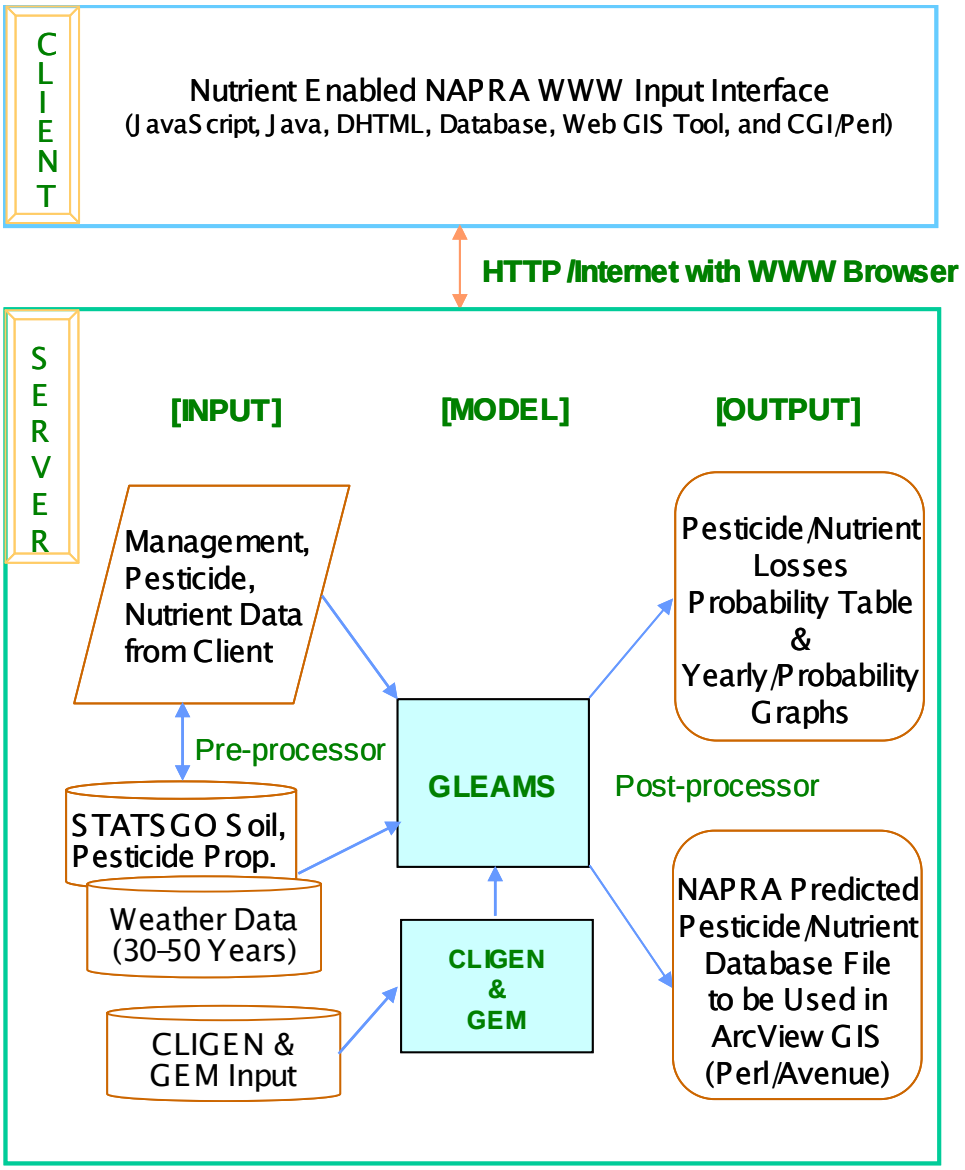
The NAPRA WWW system is available and accessible on a server at Purdue University (Engel and Lee, 2000). The benefit of using this application was that the soils database, State Soil Geographic (STATSGO), the climate databases, and the chemical databases were already included in the system. While the NAPRA WWW system is available for use by the general public on a case-by-case basis (http://danpatch.ecn.purdue.edu/~napra/SingleField/mainFrame.html), the program was run in batch mode on the server at Purdue University to better accommodate the high number of soil types within the State of Texas. Batch runs also allowed the efficient consideration of multiple chemicals. Dr. Bernard Engel, Department Head, Department of Agricultural and Biological Engineering, Purdue University, set up the batch files and ran the NAPRA WWW program. Outputs from the NAPRA WWW program (hereafter, the NAPRA WWW program is referred to as NAPRA GLEAMS) were provided in an ArcGIS format for analysis.

Descriptions of the various aspects of the NAPRA GLEAMS application are discussed in the following paragraphs. **Figure 2-1** contains a schematic of the NAPRA GLEAMS application and the various components necessary for its use (adapted from Lim and Engel, 2003).

2.1.1 Soils Database

The STATSGO soil database was designed primarily for regional, multi-state, river basin, state, and multi-county resource planning, management, and monitoring. STATSGO soils data are mapped on a 1:250,000 scale within a one by two degree topographic quadrangle unit. These quadrangle units are distributed by state. Within any single map unit identification (muid) on a STATSGO soil map, there may be up to 21 components of soil for which there are attributes, some in different layers. The website http://dbwww.essc.psu.edu/dbtop/amer_n/us_sc/tx/data/soilprop/statsgo/doc. html contains further information on the STATSGO database for the State of Texas.

FIGURE 2-1
SCHEMATIC OF NAPRA GLEAMS APPLICATION FLOWCHART



Source: Lim and Engel, 2003

Soil parameters necessary for the NAPRA GLEAMS simulation include: 1) saturated conductivity; 2) rooting depth; 3) soil water content; 4) number of soil horizons; 5) depth to each soil horizon; 6) porosity; 7) field capacity; 8) organic matter content; 9) water content at wilting point; 10) clay content; 11) silt content; 12) pH; and 13) others (refer to the GLEAMS User's Manual (Knisel and Davis, 2000) for further information on these parameters). These soil parameters are contained within the STATSGO database. The STATSGO database for the State of Texas contains information on 624 different soils.

2.1.2 Climate Generator

The climate generator used in the NAPRA application of GLEAMS is called CLIGEN. It is a stochastic weather generator, which produces daily estimates of precipitation, temperature, dewpoint, wind, and solar radiation for a single geographic point, using monthly parameters (means, standard deviations, skewness, etc.) derived from the historic measurements (USDA, 2005). Station parameters files to run CLIGEN for several thousand sites in the United States are available, and CLIGEN uses these parameters from the observed period of record at a particular site to generate the weather/climate outputs. There is no other interaction between NAPRA GLEAMS and CLIGEN, beyond simulating the weather. The weather parameters necessary for a NAPRA GLEAMS simulation are precipitation, daily maximum and minimum temperature, and others. Please refer to the GLEAMS User's Manual (Knisel and Davis, 2000) for further information on weather input parameters. More information on CLIGEN can be found at http://horizon.nserl.purdue.edu/Cligen/.

Twenty-three weather stations in Texas were used in this modeling effort. **Figure 2-2** is a map depicting the different weather stations across the State of Texas used for the simulations.

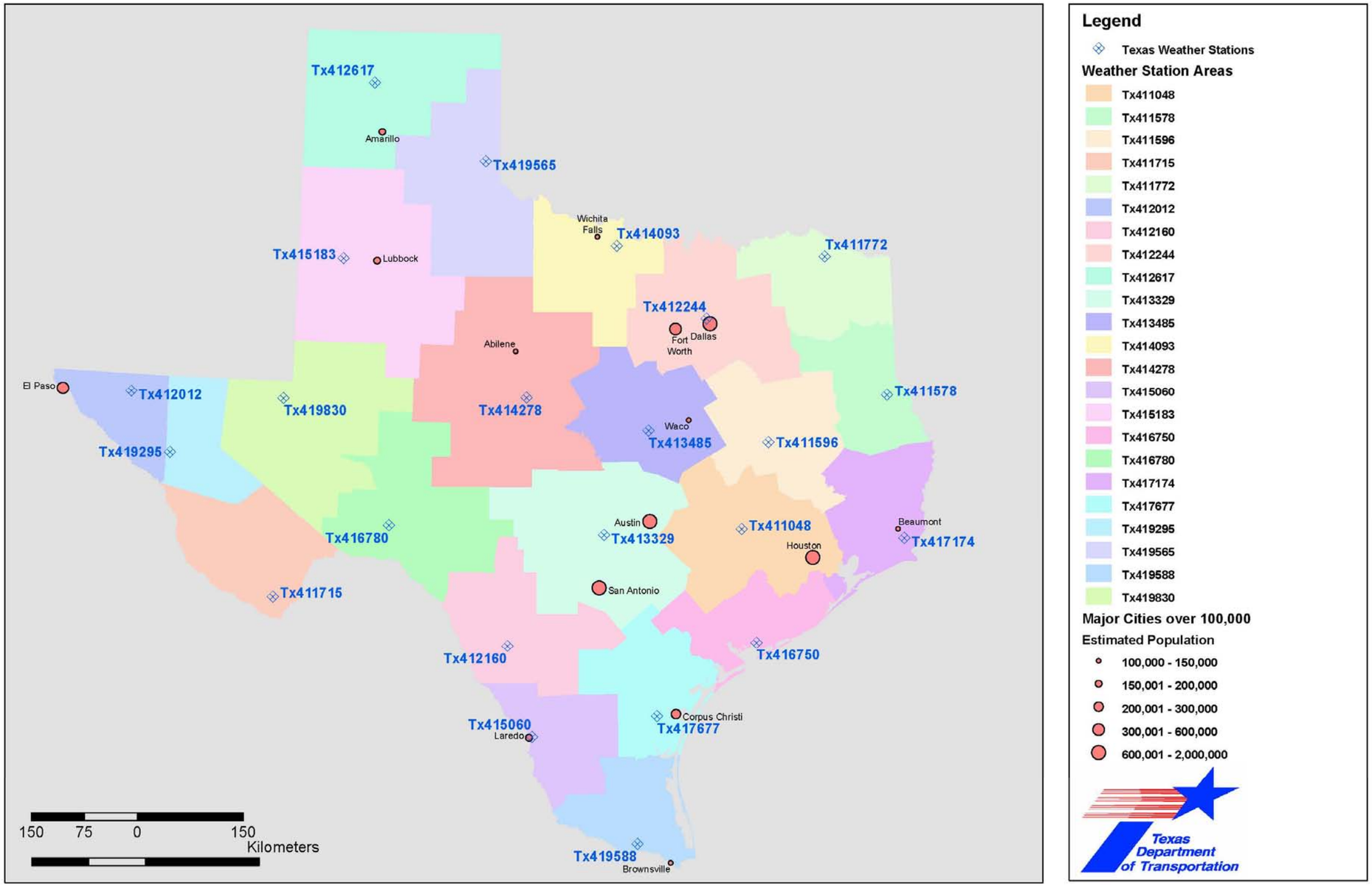
As shown in **Figure 2-2**, a Theissen polygon was assigned to each weather station. Theissen polygons are constructed by first joining the locations of adjacent weather stations by lines and then constructing perpendicular bisectors of those lines, which form polygons around each station. The polygons were adjusted so that the edges followed the county boundaries.

2.1.3 Chemical Information

2.1.3.1 Chemical Properties

The properties of the chemicals that were necessary for this effort were tabulated and used as input parameters in the NAPRA GLEAMS model runs. NAPRA GLEAMS has a chemical database lookup function built into the application. However, some chemicals were not in the database. In these cases, chemical specific input parameters were obtained from other sources. In a few cases, chemical specific input parameters could not be located from any source so assumptions based on professional judgment were made and the rationale noted (see next paragraph). **Table 2-1** shows the chemical properties of the pesticides modeled in this effort.

FIGURE 2-2
WEATHER STATION LOCATIONS



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The chemical properties necessary for a simulation of NAPRA GLEAMS included soil and foliar half-lives, solubility, organic carbon partition coefficient (K_{oc}), and wash off fraction. Wash off fraction was estimated for some chemicals due to the limited information available. When assumptions for wash off fraction were necessary, a conservative value of 0.95 or 95 percent was used. Foliar half-life was estimated at 67 to 75 percent of the soil half-life when information was not available for this parameter; again, conservative when compared to the percentages of obtained from chemicals with known foliar half-lives and soil half-lives.

TABLE 2-1
PESTICIDE PROPERTIES

Active Ingredient	Soil Half-Life (days)	Water Solubility (mg/L)	K_{oc} (L/kg)	Wash off Fraction	Foliar Half-Life (days)
Amino pyralid	34.5 (a)	2,480 (a)	10.8 (a)	0.95 (b)	23 (c)
Chlorsulfuron	160 (e)	7,000 (d,e)	40 (d,e)	0.75 (e)	30 (e)
Clopyralid	30 (e)	1,000 (e)	6 (e)	0.95 (e)	2 (e)
Fenoxycarb	1 (d,e)	6 (d,e)	1,000 (d,e)	0.95 (b)	1 (b)
Fluroxypyr	36.3 (e)	13,6000 (e)	200 (e)	0.95 (b)	24 (c)
Glyphosate	47 (d,e)	12,000 (d,e)	24,000 (d,e)	0.6 (e)	3 (e)
Imazapyr	90 (e)	11,000 (e)	100 (e)	0.9 (e)	30 (e)
Metsulfuron methyl	120 (e)	9,500 (e)	35 (e)	0.8 (e)	30 (e)
Sulfometuron methyl	20 (e)	70 (e)	78 (e)	0.65 (e)	10 (e)
Sulfosulfuron	50 (e)	1,626.8 (e)	47 (e)	0.95 (b)	38 (c)
Triclopyr	155 (e)	435 (e)	27 (e)	0.95 (b)	15 (f)

Notes:

(a) Amino pyralid Technical Bulletin, Dow Agrosciences

(b) Conservatively assumed

(c) Assumed to be 0.67 to 0.75 of the soil half life

(d) Mackay, D., Shiu, W., Ma, K. (1999) *Physical-Chemical Properties and Environmental Fate Handbook* (CD-ROM). Chapman & Hall/CRCnetBASE, Boca Raton Florida

(e) National Resource Conservation Service Pesticide Database, http://www.wcc.nrcs.usda.gov/pestmgt/winpst.html

(f) *Triclopyr -Revised Human Health and Ecological Risk Assessments, Final Report* Prepared for: USDA, Forest Service, by Syracuse Environmental Research Associates, Inc., 3/15/2003

Source: Project Team

2.1.3.2 Application Rates

TxDOT's Herbicide Operations Manual (TxDOT, 2004) contained the application rates of the different chemicals evaluated used in the model. **Table 2-2** shows the application rates used in the modeling scenarios. Since some chemical are applied at different rates to address different pest species and/or site specific conditions, 18 different application rates were modeled.

The active ingredient-loading rate was calculated for both liquid forms and solid forms of the formulations studied. For the liquid formulations, the specific gravity of the product was used in the calculations to determine the pound per acre loading rate. For the solid forms, an ounce equaled one-sixteenth of a pound.

2.1.4 Other Input Parameters

Other input parameters used in the NAPRA GLEAMS application include: 1) the land use practice; 2) slope length; 3) crop type; 4) planting date; 5) harvest date; 6) pesticide application date; 7) application method; and 8) the percentage of the soil surface covered by residue and vegetation. To better adapt the model to pest management on TxDOT ROW, specific agricultural practice input parameters like crop type were modeled as constants. The crop type was input as grass under no till conditions, land use practice was pasture or range, with a planting date of May 15. The slope length constant was 100 feet. The application method for the pesticides was assumed to be a broadcast spray surface application, with 90 percent of the chemical applied to the plants, and 10 percent applied to the soil.

The pesticide application dates varied from chemical to chemical, depending on the target and they are provided in **Table 2-2**. The dates of application were determined from the Herbicide Operations Manual (TxDOT, 2004), from personal communication with TxDOT personnel, and from the product labels. The significance of the application date is apparent when the interaction of the climate and the pesticide movement is simulated, since the weather generated by CLIGEN shortly after an application will affect the resulting runoff and leaching of the chemical. In general, greater rainfall increases the potential for pesticide loss to runoff and groundwater.

TABLE 2-2
APPLICATION RATES AND TIMING

Active Ingredient	Trade Name	Formulation	Maximum	Average	Other (if needed)	Timing	Active Ingredient %	Notes
Clopyralid	Transline	liquid	21 oz/acre for kudzu (0.4925 lb/acre active ingredient)	10 oz/acre (0.2345 lb/acre active ingredient)		July 31 (maximum) and April 30 (average)	31%	Specific gravity = 1.161
Fenoxycarb	Award	solid	1 lb/acre (0.01 lb/acre active ingredient)			April 30	1%	
Fluroxypyr	Vista	liquid	10 oz/acre (0.1174 lb/acre active ingredient)			April 30	18.20%	Specific gravity = 0.99
Glyphosate	Roundup Pro	liquid	4 qts/acre (3 lb/acre active ingredient)	8 oz/acre (0.1875 lb/acre active ingredient)	16 oz/acre (0.3735 lb/acre active ingredient)	Maximum rate: one application on July 15; average rate: one application on June 15; other rate: one application on March 30	Roundup Pro 41% glyphosate, 31% acid equivalent	Specific gravity = 1.1655
Glyphosate	Roundup Original Max	liquid	2.67 qts/acre (3 lb/acre active ingredient)	5.33 oz/acre (0.1875 lb/acre active ingredient)	10.67 oz/acre (0.3735 lb/acre active ingredient)	Maximum rate: one application on July 15; average rate: one application on June 15; other rate: one application on March 30	4.5 pounds glyphosate/US Gallon	No difference in application rate of active ingredient from Roundup Pro
Imazapyr	Habitat & Arsenal	liquid	Habitat (2 qt/acre) (0.99 lb/acre active ingredient)			May 1	Habitat 22.6%	Specific Gravity = 1.04-1.07
Metsulfuron methyl	Escort XP	solid	3 oz/acre (0.1125 lb/acre active ingredient)	1 oz/acre (0.0375 lb/acre active ingredient)		Maximum rate: one application on September 15; average rate: one application on June 15	60% Escort	

TABLE 2-2
APPLICATION RATES AND TIMING

Active Ingredient	Trade Name	Formulation	Maximum	Average	Other (if needed)	Timing	Active Ingredient %	Notes
Sulfometuron methyl	Oust XP	solid	2 oz/acre (0.09375 lb/acre active ingredient)			One application on July 15	75% Oust XP	This rate is actually the smallest, when compared to the two rates used in Landmark
Sulfosulfuron	Outrider	solid	1.33 oz/acre (0.0623 lb/acre active ingredient)			One application on June 15	75%	
Triclopyr	Garlon 3a	liquid	1 quart/acre (0.75 lb/acre active ingredient)			July 31	Garlon 3a - 31.8%	Garlon 3a S.G = 1.135
Sulfometuron methyl	Landmark MP	solid	2 oz/acre (0.0703 lb/acre active ingredient)	1 oz/acre (0.0352 lb/acre active ingredient)		July 15	Sulfometuron 56.25% and chorsulfuron (telar) 18.75%	
Chlorsulfuron (telar)			0.0234 lb/acre active ingredient	0.0117 lb/acre active ingredient				
Amino pyralid	Milestone VM	liquid	7 oz/acre (0.1097 lb/acre)			April 30	2 pounds/gallon, or 21.1 % a.e.	

Source: Project Team

3.0 MODEL RESULTS AND DISCUSSION

3.1 MODEL OUTPUT FORMAT

NAPRA GLEAMS yields a mass of chemical per unit area as an output. Mass lost in runoff water, mass leached to the bottom of the root zone, and mass adsorbed to eroded soils were calculated using the model. The units of the model output are in grams per hectare (g/ha).

As a part of the NAPRA GLEAMS simulations, the soils database and the information from weather stations were combined spatially. As noted in Sections 2.1.1 and 2.1.2, the STATSGO soils database and weather information from 23 weather stations were used. Within each Theissen polygon superimposed on the State of Texas, several hundred soils can be present. When the weather polygons were superimposed over the soils data 4,600 possible combinations were produced. The model was adjusted when locations were classified as "water." Approximately 150 areas with the "water" classification were removed from the model resulting in approximately 4,450 unique combinations of soil and weather polygons.

NAPRA GLEAMS results from these 4,450 combinations were obtained for each of the 60 years of CLIGEN weather information used in the model. For each model run of a particular chemical and a particular application rate, there were 4,450 different weather/soil areas times 60 years, or over 267,000 results for runoff of each chemical and 267,000 results for leaching of each chemical. The runoff and leaching results for this 60-year period were then summarized and ranked for each unique weather/soil combination. Results were then reported by percent probability of exceedance at the 50 percent, 25 percent, 10 percent, and 5 percent level. For instance, the 50 percent probability of exceedance for runoff mass in any one weather/soil area would be that runoff mass, which when ranked from highest to lowest over the 60 year time period, was the 30th or middle value in the list of 60 ranked runoff masses (i.e., 50 percent of the yearly values are greater and 50 percent are less than the 30^{th} year ranking).

The mass per unit area (hectare) output results for runoff and leaching were converted to concentrations in runoff at the edge of the field (i.e., ROW) and concentration in leached water at the bottom of the root zone. The concentrations in parts per billion (ppb) were found from the mass results by dividing the mass by the volume of water. A volume of water was determined by dividing one hectare (10,000 meters squared)

times a depth corresponding to the runoff in inches (output of NAPRA GLEAMS) or water leached in inches (output of NAPRA GLEAMS). Appropriate conversions were made to obtain parts per billion or micrograms per liter (ug/L).

3.2 HYDROLOGY OUTPUT

Hydrologic results from the NAPRA GLEAMS application for the State of Texas are summarized in **Table 3-1**. This table also includes the statistical summaries of inches of runoff and inches of percolated water resulting from all the combinations of weather and soil, further classified by probability of exceedances of runoff water and percolation water. On the average, a greater volume of water is likely to percolate into the ground from rain events across the State of Texas, than is likely to occur as runoff.

TABLE 3-1
HYDROLOGY OUTPUT FROM NAPRA GLEAMS

Runoff (inches)	Average	SD	Median	Max	Min
5% Probability of Exceedance	4.656	3.588	3.933	21.526	0
10% Probability of Exceedance	3.624	3.116	2.938	20.419	0
25% Probability of Exceedance	2.440	2.447	1.644	16.646	0
50% Probability of Exceedance	1.539	1.792	0.971	13.283	0
Percolation (inches)	**Average**	**SD**	**Median**	**Max**	**Min**
5% Probability of Exceedance	12.561	8.224	11.425	46.467	0
10% Probability of Exceedance	10.972	7.691	10.347	42.173	0
25% Probability of Exceedance	8.194	6.678	6.496	35.186	0
50% Probability of Exceedance	5.961	5.677	4.214	29.953	0

Notes:
SD = standard deviation

Source: Project Team

Figure 3-1 and **Figure 3-2** depict the distribution of the runoff and percolation across the State of Texas for the five percent probability of exceedance results. As shown in **Figure 3-1**, the runoff in inches across the state can range from zero to 21.5 inches depending on location. The inches of percolated water across the state range from zero to 46.5 inches as shown in **Figure 3-2**. By comparing the two figures, locations can be found where the resulting runoff is higher than the percolated water, which would be expected in areas where clay soil predominates or areas with steeper slopes.

FIGURE 3-1
RUNOFF IN INCHES
(5% Probability of Exceedance)

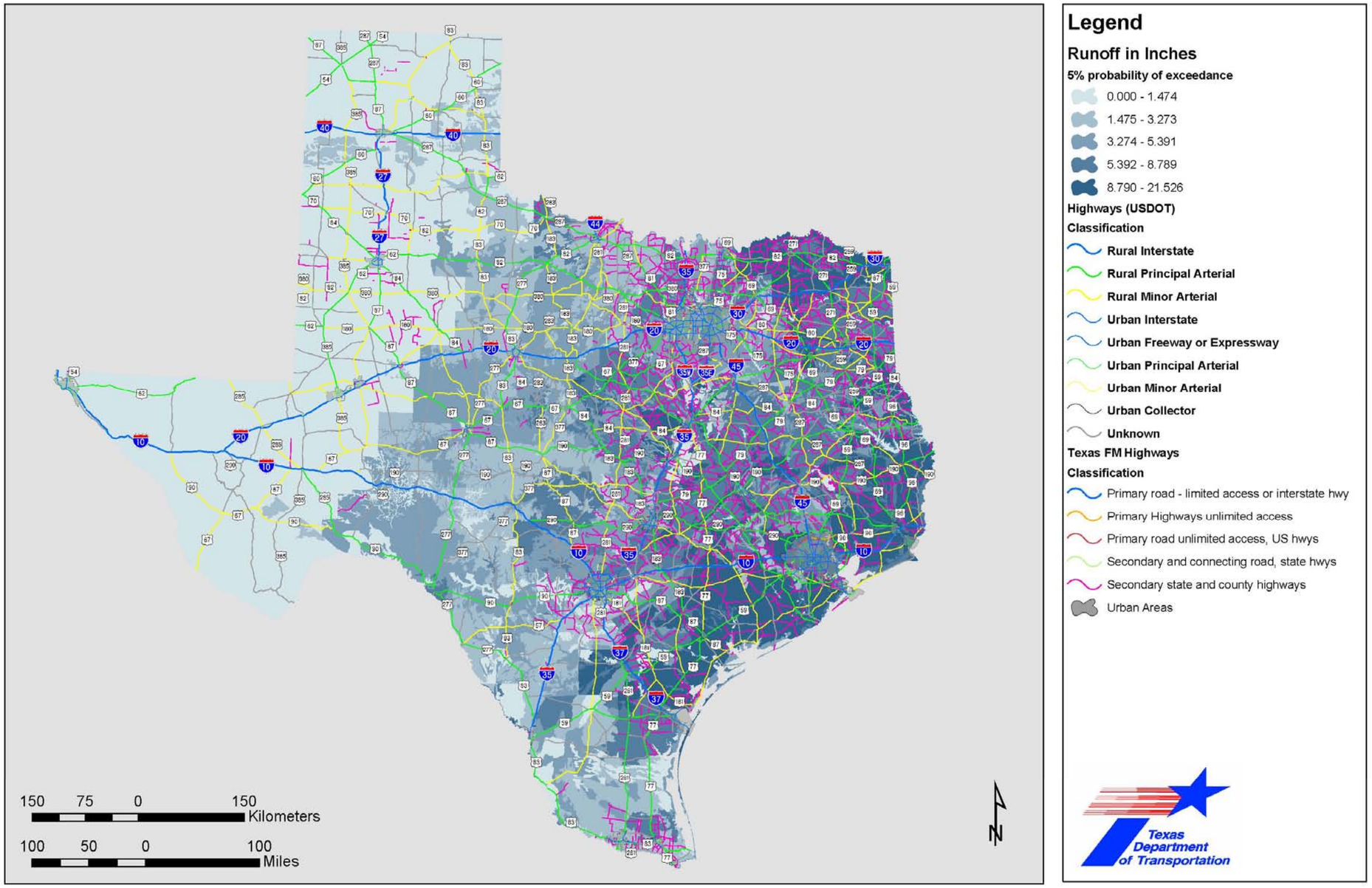

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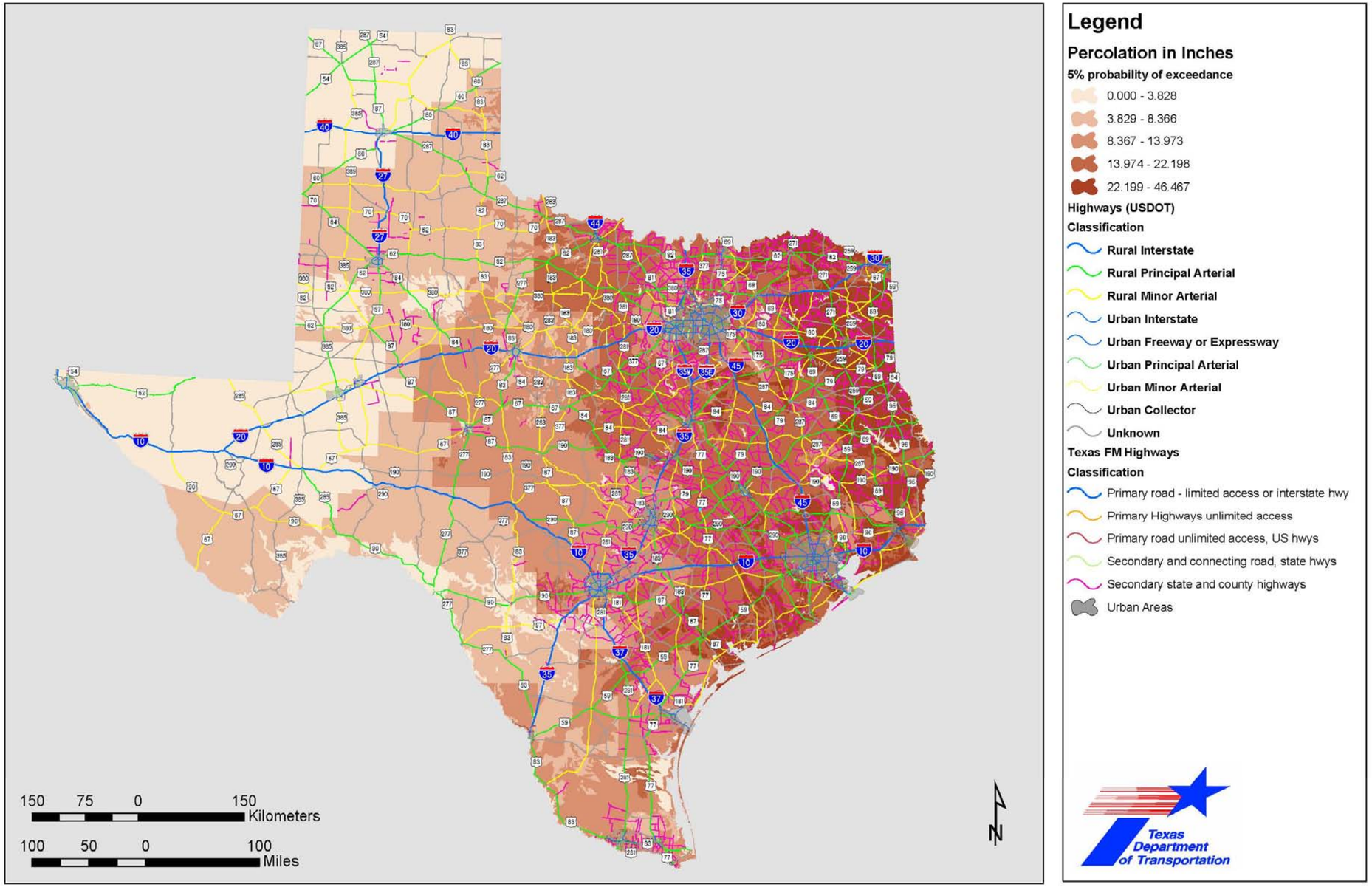
FIGURE 3-2
PERCOLATION IN INCHES
(5% Probability of Exceedance)



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3.3 CHEMICAL SPECIFIC RESULTS

NAPRA GLEAMS results are provided for each chemical. Summary tables as well as maps of Texas with graphical results are also provided. The statistics presented on the summary tables are representative of all the results across the State of Texas, that is, of all 4,450 different soil/weather combinations. For location specific results, the maps included with this report provide more detailed information, as does the ArcGIS project maintained by TxDOT MNT.

In general, the average value of the results was usually higher than the median, indicating that the data are skewed toward lower values. In addition, the standard deviation of each set of data was high when compared to the average, which suggests wide variability in the data in the ranges above the average value.

3.3.1 Glyphosate

Glyphosate is the active ingredient in the Roundup brand of herbicides, as well as Aquamaster. Aquamaster was not modeled by the NAPRA GLEAMS model because it is applied to aquatic (i.e., emergent plants) not terrestrial environments. Two formulations of glyphosate were modeled, including Roundup Pro and Roundup Original Max. Since the application rates of each of these products produce identical loading rates of glyphosate, there is no distinction in the model output for the two products. Three different application rates were modeled with NAPRA GLEAMS.

Table 3-2, **Table 3-3**, and **Table 3-4** contain the summary statistics of the NAPRA GLEAMS model output for the three application rates of glyphosate. In general, glyphosate tends to be present more in the runoff water than in the percolated water. Evidence of this trend can be seen by comparing runoff to leaching results and is likely due to the high organic carbon partition coefficient (K_{oc}) value for glyphosate. A high K_{oc} value means that the chemical has a high affinity for organic carbon in the soil. As expected, more mass is present in the runoff and leaching to groundwater scenarios for the higher application rates. Higher application rates result in higher concentrations in the runoff water and the leaching water.

Exhibits A.1 through **A.3** depict the runoff results for glyphosate at the five percent probability of exceedance level for the three application rates across the State of Texas. **Exhibits A.4** through **A.6** show the leaching to groundwater results at the five percent probability of exceedance level (exhibits are located at the end of the report).

TABLE 3-2
GLYPHOSATE RESULTS, 8 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.62634	0.57991	0.466	4.357	0.000
10% Probability of Exceedance	0.40580	0.39223	0.321	2.960	0.000
25% Probability of Exceedance	0.20369	0.22497	0.146	1.670	0.000
50% Probability of Exceedance	0.08775	0.11441	0.055	0.974	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.54442	3.53656	0.000	40.163	0.000
10% Probability of Exceedance	0.34259	2.16673	0.000	21.683	0.000
25% Probability of Exceedance	0.18865	1.23916	0.000	12.984	0.000
50% Probability of Exceedance	0.06951	0.48303	0.000	5.490	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.50056	0.26151	0.430	1.951	0.000
10% Probability of Exceedance	0.41287	0.21597	0.370	1.725	0.000
25% Probability of Exceedance	0.29409	0.16565	0.267	1.207	0.000
50% Probability of Exceedance	0.19997	0.13021	0.171	0.978	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.23395	1.31429	0.000	15.713	0.000
10% Probability of Exceedance	0.18180	1.01546	0.000	13.390	0.000
25% Probability of Exceedance	0.12937	0.80118	0.000	11.315	0.000
50% Probability of Exceedance	0.08684	0.58301	0.000	8.008	0.000

Notes:
Application rate: 8 oz/acre Roundup Pro or 5.33 oz/acre Roundup Original Max
Glyphosate: 0.1875 pound/acre, 210.35 gram/hectare
Application date: June 15

Source: Project Team

TABLE 3-3
GLYPHOSATE RESULTS, 16 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	1.48558	1.61417	1.079	11.795	0.000
10% Probability of Exceedance	1.05965	1.12003	0.792	7.254	0.000
25% Probability of Exceedance	0.50513	0.61181	0.325	4.005	0.000
50% Probability of Exceedance	0.21686	0.30885	0.123	1.984	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.70130	4.14759	0.000	51.199	0.000
10% Probability of Exceedance	0.50587	3.05402	0.000	36.547	0.000
25% Probability of Exceedance	0.26870	1.72326	0.000	22.198	0.000
50% Probability of Exceedance	0.09347	0.59756	0.000	8.113	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	1.04260	0.79766	0.855	7.090	0.000
10% Probability of Exceedance	0.93222	0.67276	0.810	4.280	0.000
25% Probability of Exceedance	0.62635	0.46325	0.542	2.610	0.000
50% Probability of Exceedance	0.40775	0.30886	0.349	1.955	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.24527	1.31971	0.000	12.180	0.000
10% Probability of Exceedance	0.20447	1.09983	0.000	9.855	0.000
25% Probability of Exceedance	0.15423	0.92610	0.000	9.676	0.000
50% Probability of Exceedance	0.09110	0.55673	0.000	5.251	0.000

Notes:
Application rate: 16 oz/acre Roundup Pro or 10.67 oz/acre Roundup Original Max
Glyphosate: 0.3735 pound/acre, 419.02 gram/hectare, application date: March 30

Source: Project Team

TABLE 3-4
GLYPHOSATE RESULTS, 4 QTS/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	16.58225	15.52793	12.264	98.130	0.000
10% Probability of Exceedance	11.21555	10.42044	9.040	76.693	0.000
25% Probability of Exceedance	6.14843	6.31638	4.946	44.833	0.000
50% Probability of Exceedance	2.98555	3.82422	1.875	30.356	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	13.62657	77.26897	0.000	743.937	0.000
10% Probability of Exceedance	11.15937	67.12764	0.000	679.074	0.000
25% Probability of Exceedance	7.48959	47.91607	0.000	473.032	0.000
50% Probability of Exceedance	3.08900	21.39847	0.000	216.795	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	14.05001	8.47333	12.494	73.985	0.000
10% Probability of Exceedance	12.32356	6.88922	10.510	56.798	0.000
25% Probability of Exceedance	9.65177	5.49985	8.496	49.409	0.000
50% Probability of Exceedance	6.82866	4.47474	6.074	32.331	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	6.99850	39.64650	0.000	581.782	0.000
10% Probability of Exceedance	6.51721	36.80894	0.000	509.638	0.000
25% Probability of Exceedance	5.60387	34.19311	0.000	492.023	0.000
50% Probability of Exceedance	3.50903	22.57270	0.000	220.153	0.000

Notes:
Application rate: 4 quarts/acre Roundup Pro or 2.67 quart/acre Roundup Original Max
Glyphosate: 3 pound/acre, 3,365.64 gram/hectare, application date: July 15

Source: Project Team

3.3.2 Sulfometuron Methyl

Sulfometuron methyl is the active ingredient in the Oust brand of herbicides, as well as one of the active ingredients in Landmark MP. Because of its presence in two different chemical formulations, it was necessary to model three different application rates for this chemical.

Table 3-5, **Table 3-6**, and **Table 3-7** contain the summary statistics of the NAPRA GLEAMS model output for the three application rates of sulfometuron methyl. In general, sulfometuron methyl tends to be present more so in the percolated water than in the runoff water. As expected, more mass is present in the runoff and leaching to groundwater scenarios for the higher application rates. Similar comparisons can be made with the concentration values. Higher application rates result in higher concentrations in the runoff water and the leaching water. The Oust brand application of this compound resulted in the highest concentrations.

Exhibits B.1 through **B.3** depict the runoff results for sulfometuron methyl at the five percent probability of exceedance level for the three application rates across the State of Texas. **Exhibits B.4** through **B.6** show the leaching to groundwater results at the five percent probability of exceedance level.

TABLE 3-5
SULFOMETURON METHYL RESULTS, OUST 2 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.19576	0.33545	0.047	2.101	0.000
10% Probability of Exceedance	0.12931	0.23071	0.025	1.405	0.000
25% Probability of Exceedance	0.04971	0.10254	0.007	0.739	0.000
50% Probability of Exceedance	0.01811	0.04304	0.002	0.338	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.81172	1.73364	0.171	16.442	0.000
10% Probability of Exceedance	0.45460	1.18187	0.069	11.405	0.000
25% Probability of Exceedance	0.17207	0.58966	0.015	6.710	0.000
50% Probability of Exceedance	0.04759	0.22174	0.001	3.358	0.000

TABLE 3-5
SULFOMETURON METHYL RESULTS, OUST 2 OZ/ACRE RATE

Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.12412	0.16566	0.048	1.297	0.000
10% Probability of Exceedance	0.10022	0.14191	0.035	0.871	0.000
25% Probability of Exceedance	0.05669	0.08300	0.015	0.411	0.000
50% Probability of Exceedance	0.03112	0.05078	0.007	0.309	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.28879	0.71502	0.073	8.924	0.000
10% Probability of Exceedance	0.18341	0.51174	0.037	6.747	0.000
25% Probability of Exceedance	0.08599	0.35088	0.009	5.696	0.000
50% Probability of Exceedance	0.02445	0.11188	0.001	1.059	0.000

Notes:
Application rate: 2 oz/acre Oust
Sulfometuron methyl: 0.09375 pound/acre, 105.18 gram/hectare
Application date: July 15

Source: Project Team

TABLE 3-6
SULFOMETURON METHYL RESULTS, LANDMARK MP 2 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.13727	0.22150	0.034	1.218	0.000
10% Probability of Exceedance	0.09087	0.15813	0.018	0.924	0.000
25% Probability of Exceedance	0.03745	0.07859	0.005	0.581	0.000
50% Probability of Exceedance	0.01322	0.03180	0.001	0.248	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.56015	1.20970	0.120	11.445	0.000
10% Probability of Exceedance	0.29329	0.80574	0.040	7.878	0.000
25% Probability of Exceedance	0.11306	0.40427	0.009	4.643	0.000
50% Probability of Exceedance	0.02910	0.13816	0.001	2.214	0.000

TABLE 3-6
SULFOMETURON METHYL RESULTS, LANDMARK MP 2 OZ/ACRE RATE

Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.10287	0.19832	0.032	1.592	0.000
10% Probability of Exceedance	0.07531	0.11103	0.025	0.706	0.000
25% Probability of Exceedance	0.04414	0.06978	0.010	0.411	0.000
50% Probability of Exceedance	0.02244	0.03734	0.005	0.216	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.22422	0.54871	0.043	6.536	0.000
10% Probability of Exceedance	0.12837	0.36687	0.021	5.022	0.000
25% Probability of Exceedance	0.05627	0.24219	0.005	3.915	0.000
50% Probability of Exceedance	0.01563	0.07841	0.000	0.776	0.000
Notes: Application rate: 2 oz/acre Landmark MP Sulfometuron methyl: 0.0703 pound/acre 78.868 gram/hectare, application date: July 15					

Source: Project Team

TABLE 3-7
SULFOMETURON METHYL RESULTS, LANDMARK MP 1 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.06864	0.11075	0.017	0.609	0.000
10% Probability of Exceedance	0.04543	0.07907	0.009	0.462	0.000
25% Probability of Exceedance	0.01873	0.03930	0.003	0.291	0.000
50% Probability of Exceedance	0.00661	0.01590	0.001	0.124	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.28007	0.60485	0.060	5.723	0.000
10% Probability of Exceedance	0.14664	0.40287	0.020	3.939	0.000
25% Probability of Exceedance	0.05653	0.20213	0.005	2.322	0.000
50% Probability of Exceedance	0.01455	0.06908	0.001	1.107	0.000

TABLE 3-7
SULFOMETURON METHYL RESULTS, LANDMARK MP 1 OZ/ACRE RATE

Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.05143	0.09916	0.016	0.796	0.000
10% Probability of Exceedance	0.03765	0.05551	0.013	0.353	0.000
25% Probability of Exceedance	0.02207	0.03489	0.005	0.206	0.000
50% Probability of Exceedance	0.01122	0.01867	0.003	0.108	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.11211	0.27436	0.022	3.268	0.000
10% Probability of Exceedance	0.06418	0.18343	0.011	2.511	0.000
25% Probability of Exceedance	0.02814	0.12110	0.003	1.958	0.000
50% Probability of Exceedance	0.00781	0.03920	0.000	0.388	0.000
Notes: Application rate: 1 oz/acre Landmark MP Sulfometuron methyl: 0.0352 pound/acre, 39.49 gram/hectare, application date: July 15					

Source: Project Team

3.3.3 Sulfosulfuron

Sulfosulfuron is the active ingredient in Outrider. One application rate of this compound was modeled. **Table 3-8** contains the summary statistics of the NAPRA GLEAMS model output for sulfosulfuron. In general, sulfosulfuron tends to be present more in the leaching water than in the runoff water, as can be seen when a comparison of runoff versus leaching results is made. Similar comparisons can be made with the concentration values. The concentrations resulting from the use of sulfosulfuron are low relative to the other chemicals used or planned for sue in the program. **Exhibits C.1** and **C.2** depict the runoff results and leaching to groundwater results for sulfosulfuron at the five percent probability of exceedance level across the state of Texas.

TABLE 3-8
SULFOSULFURON RESULTS

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.09161	0.21242	0.026	2.022	0.000
10% Probability of Exceedance	0.04874	0.10467	0.013	0.750	0.000
25% Probability of Exceedance	0.02436	0.04926	0.005	0.294	0.000
50% Probability of Exceedance	0.01260	0.02697	0.002	0.170	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	4.63186	4.98049	2.999	34.874	0.000
10% Probability of Exceedance	3.25641	4.05378	1.827	30.032	0.000
25% Probability of Exceedance	1.80223	2.81665	0.714	21.370	0.000
50% Probability of Exceedance	0.81938	1.61527	0.120	15.166	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.06969	0.09273	0.038	0.624	0.000
10% Probability of Exceedance	0.05183	0.06130	0.025	0.291	0.000
25% Probability of Exceedance	0.04005	0.05096	0.016	0.315	0.000
50% Probability of Exceedance	0.03154	0.04726	0.007	0.320	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	1.55247	1.77111	0.983	15.202	0.000
10% Probability of Exceedance	1.23365	1.55326	0.806	15.047	0.000
25% Probability of Exceedance	0.78535	1.28407	0.422	14.148	0.000
50% Probability of Exceedance	0.38795	0.81136	0.135	9.047	0.000

Notes:
Application rate: 1.33 oz/acre Outrider
Sulfosulfuron: 0.0623 pound/acre, 69.89 gram/hectare, application date: June 15

Source: Project Team

3.3.4 Metsulfuron Methyl

Metsulfuron methyl is the active ingredient in the Escort XP brand of herbicides. Two different application rates for this chemical were modeled. **Table 3-9** and **Table 3-10** contain the summary statistics of the NAPRA GLEAMS model output for the two application rates of metsulfuron methyl. The results indicate a tendency for the chemical to surface in the percolation water rather than the runoff water, likely due to a

low K_{oc} value for this compound. As expected, more mass is present in the runoff and leaching to groundwater scenarios for the higher application rate. Similar comparisons can be made with the concentration values.

Exhibits D.1 and **D.2** depict the runoff results for metsulfuron methyl at the five percent probability of exceedance level for the two application rates. **Exhibits D.3** and **D.4** show the leaching to groundwater results at the five percent probability of exceedance level.

TABLE 3-9
METSULFURON METHYL RESULTS, 1 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.17224	0.18229	0.126	1.248	0.000
10% Probability of Exceedance	0.09299	0.10756	0.058	0.776	0.000
25% Probability of Exceedance	0.04135	0.06076	0.016	0.427	0.000
50% Probability of Exceedance	0.01683	0.03181	0.004	0.252	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	11.92255	9.60740	9.617	50.508	0.000
10% Probability of Exceedance	8.01618	7.99603	5.258	47.353	0.000
25% Probability of Exceedance	5.31278	5.96411	2.921	34.339	0.000
50% Probability of Exceedance	3.34600	4.28372	1.160	24.909	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.33662	0.64408	0.114	5.756	0.000
10% Probability of Exceedance	0.25791	0.43557	0.076	6.491	0.000
25% Probability of Exceedance	0.17917	0.42457	0.039	2.457	0.000
50% Probability of Exceedance	0.11787	0.35312	0.012	2.362	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	3.33873	2.02169	3.204	14.996	0.000
10% Probability of Exceedance	2.41213	1.73625	2.263	13.502	0.000
25% Probability of Exceedance	1.99324	1.64596	1.827	13.207	0.000
50% Probability of Exceedance	1.51252	1.46874	1.225	11.423	0.000

Notes:
Application rate: 1 oz/acre Escort XP
Metsulfuron methyl: 0.0375 pound/acre, 42.07 gram/hectare, application date: June 15

Source: Project Team

TABLE 3-10
METSULFURON METHYL RESULTS, 3 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.50128	0.50857	0.379	3.166	0.000
10% Probability of Exceedance	0.27061	0.31542	0.167	2.328	0.000
25% Probability of Exceedance	0.12414	0.18272	0.048	1.299	0.000
50% Probability of Exceedance	0.05071	0.09555	0.013	0.758	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	34.48972	29.39006	25.737	153.176	0.000
10% Probability of Exceedance	24.40149	24.43936	16.457	144.403	0.000
25% Probability of Exceedance	16.35305	18.24286	8.738	104.637	0.000
50% Probability of Exceedance	10.43509	13.14634	4.048	77.285	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.98230	1.85544	0.339	17.259	0.000
10% Probability of Exceedance	0.76856	1.30861	0.227	19.472	0.000
25% Probability of Exceedance	0.53896	1.27454	0.124	7.370	0.000
50% Probability of Exceedance	0.34362	1.01066	0.039	7.179	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	9.51985	6.08851	8.888	46.653	0.000
10% Probability of Exceedance	7.36295	5.19659	6.945	40.049	0.000
25% Probability of Exceedance	6.21455	5.00133	5.593	39.927	0.000
50% Probability of Exceedance	4.85169	4.45411	3.906	34.767	0.000

Notes:
Application rate: 3 oz/acre Escort XP
Metsulfuron methyl: 0.1125 pound/acre, 126.21 gram/hectare, application date: September 15

Source: Project Team

3.3.5 Fluroxypyr

Fluroxypyr is the active ingredient in the Vista brand of herbicide. Only one application rate of this compound was modeled. **Table 3-11** contains the summary statistics of the NAPRA GLEAMS model output for fluroxypyr. In general, fluroxypyr tends to be equally likely to occur in runoff water and percolated water. **Exhibits E.1** and **E.2** depict the runoff results and leaching to groundwater results for fluroxypyr at the five percent probability of exceedance level across the State of Texas.

TABLE 3-11
FLUROXYPYR RESULTS

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	1.60517	1.85963	0.888	9.044	0.000
10% Probability of Exceedance	0.98746	1.21996	0.461	5.139	0.000
25% Probability of Exceedance	0.43064	0.58087	0.154	2.477	0.000
50% Probability of Exceedance	0.15542	0.24033	0.039	1.257	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	1.53219	4.69845	0.100	57.405	0.000
10% Probability of Exceedance	0.99762	3.62563	0.043	43.573	0.000
25% Probability of Exceedance	0.41283	1.54767	0.008	14.467	0.000
50% Probability of Exceedance	0.13926	0.61347	0.001	6.006	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	1.02345	0.89394	0.851	4.147	0.000
10% Probability of Exceedance	0.74731	0.61824	0.672	2.955	0.000
25% Probability of Exceedance	0.46568	0.43238	0.408	2.063	0.000
50% Probability of Exceedance	0.25754	0.26199	0.189	1.260	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.47732	1.36436	0.035	13.696	0.000
10% Probability of Exceedance	0.36673	1.20070	0.021	11.750	0.000
25% Probability of Exceedance	0.19845	0.79032	0.005	7.520	0.000
50% Probability of Exceedance	0.09169	0.44091	0.001	4.240	0.000

Notes:
Application rate: 10 oz/acre Vista
Fluroxypyr: 0.1174 pound/acre, 131.71 gram/hectare, application date: April 30

Source: Project Team

3.3.6 Triclopyr

Triclopyr is the active ingredient in Garlon 3a. **Table 3-12** contains the summary statistics of the NAPRA GLEAMS model output for triclopyr. The mass of triclopyr in leached water far exceeds the mass present in runoff water, which is likely due to a low K_{oc} as well as a long soil half-life for this compound relative to other chemicals. **Exhibit F.1** depicts the runoff results for triclopyr at the five percent probability of exceedance level for the given application rate across the State of Texas. **Exhibit F.2** shows the leaching to groundwater results at the five percent probability of exceedance level.

TABLE 3-12
TRICLOPYR RESULTS, GARLON 3a 1 QT/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.89827	1.12820	0.534	10.293	0.000
10% Probability of Exceedance	0.43974	0.50356	0.224	2.140	0.000
25% Probability of Exceedance	0.20300	0.29904	0.065	1.564	0.000
50% Probability of Exceedance	0.09521	0.17556	0.021	0.999	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	265.00116	178.85503	248.540	1032.244	0.000
10% Probability of Exceedance	212.99013	160.88466	185.600	909.293	0.000
25% Probability of Exceedance	143.15843	127.91645	111.597	717.784	0.000
50% Probability of Exceedance	85.92735	90.78605	52.089	547.031	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	2.07371	5.44019	0.456	59.480	0.000
10% Probability of Exceedance	1.50637	2.88761	0.298	21.033	0.000
25% Probability of Exceedance	1.07064	2.67146	0.195	15.278	0.000
50% Probability of Exceedance	0.74747	2.28650	0.069	15.463	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	83.41059	47.31748	77.288	360.256	0.000
10% Probability of Exceedance	77.30694	48.27004	70.520	425.454	0.000
25% Probability of Exceedance	65.07617	45.10912	60.756	419.837	0.000
50% Probability of Exceedance	48.63674	40.25457	46.863	448.010	0.000

Notes:
Application rate: 1 quart/acre Garlon 3a
Triclopyr: 0.75 pound/acre, 841.41 gram/hectare, application date: July 31

Source: Project Team

3.3.7 Clopyralid

Clopyralid is the active ingredient in the Transline brand of herbicides. Two different application rates for this chemical were modeled.

Table 3-13 and **Table 3-14** contain the summary statistics of the NAPRA GLEAMS model output for the two application rates of clopyralid. The results indicate a much higher tendency, approximately three orders of magnitude higher, for the chemical to end up in the percolation water than the runoff water, due to a very low K_{oc} value for

this compound. As expected, more mass is present in the runoff and leaching to groundwater scenarios for the higher application rate. Similar comparisons can be made with the concentration values.

Exhibits G.1 and **G.2** depict the runoff results for clopyralid at the five percent probability of exceedance level for the two application rates across the State of Texas. **Exhibits G.3** and **G.4** show the leaching to groundwater results at the five percent probability of exceedance level.

TABLE 3-13
CLOPYRALID RESULTS, 10 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.01350	0.03544	0.001	0.392	0.000
10% Probability of Exceedance	0.00422	0.01296	0.000	0.188	0.000
25% Probability of Exceedance	0.00067	0.00189	0.000	0.023	0.000
50% Probability of Exceedance	0.00009	0.00034	0.000	0.003	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	11.85328	14.85615	6.677	85.947	0.000
10% Probability of Exceedance	6.77565	8.37563	3.627	51.271	0.000
25% Probability of Exceedance	1.78029	2.32938	0.910	15.146	0.000
50% Probability of Exceedance	0.34134	0.64950	0.082	5.549	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.00720	0.01744	0.001	0.168	0.000
10% Probability of Exceedance	0.00232	0.00527	0.000	0.065	0.000
25% Probability of Exceedance	0.00054	0.00115	0.000	0.011	0.000
50% Probability of Exceedance	0.00014	0.00039	0.000	0.002	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	3.00276	2.75332	2.291	17.708	0.000
10% Probability of Exceedance	1.94722	1.72863	1.453	10.905	0.000
25% Probability of Exceedance	0.65567	0.68359	0.493	5.636	0.000
50% Probability of Exceedance	0.13360	0.19710	0.061	1.322	0.000

Notes:
Application rate: 10 oz/acre Transline
Clopyralid: 0.2345 pound/acre, 263.08 gram/hectare, application date: April 30

Source: Project Team

TABLE 3-14
CLOPYRALID RESULTS, 21 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.04751	0.08120	0.024	0.745	0.000
10% Probability of Exceedance	0.01947	0.02559	0.010	0.185	0.000
25% Probability of Exceedance	0.00733	0.01166	0.002	0.076	0.000
50% Probability of Exceedance	0.00272	0.00497	0.000	0.034	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	43.72960	34.50464	34.706	261.697	0.000
10% Probability of Exceedance	30.29554	26.22384	23.679	220.657	0.000
25% Probability of Exceedance	16.36841	17.17607	10.873	152.457	0.000
50% Probability of Exceedance	6.99564	10.03899	3.236	112.410	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.08331	0.18700	0.023	1.964	0.000
10% Probability of Exceedance	0.05543	0.10634	0.014	0.687	0.000
25% Probability of Exceedance	0.03403	0.09065	0.004	0.522	0.000
50% Probability of Exceedance	0.01899	0.06244	0.001	0.430	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	14.30337	10.39862	11.518	102.560	0.000
10% Probability of Exceedance	10.75388	7.97163	9.194	92.204	0.000
25% Probability of Exceedance	7.16212	6.21027	5.988	58.459	0.000
50% Probability of Exceedance	3.25971	3.70480	2.409	27.249	0.000

Notes:
Application rate: 21 oz/acre Transline
Clopyralid: 0.4925 pound/acre, 552.53 gram/hectare, application date: July 31

Source: Project Team

3.3.8 Chlorsulfuron

Chlorsulfuron is one of the active ingredients in the Landmark MP brand of herbicides. Two different application rates for this chemical were modeled. (Sulfometuron methyl is also present in Landmark MP [see Section 3.3.2]). Chlorsulfuron is also sold under the formulation name of Telar.

Table 3-15 and **Table 3-16** contain the summary statistics of the NAPRA GLEAMS model output for the two application rates of chlorsulfuron. The results indicate a higher tendency for the chemical to end up in the percolation water than the runoff water, due to a low K_{oc} value for this compound. As expected, more mass is present in the runoff and leaching to groundwater scenarios for the higher application rate.

Exhibits H.1 and **H.2** depict the runoff results for chlorsulfuron at the five percent probability of exceedance level for the two application rates across the State of Texas. **Exhibits H.3** and **H.4** show the leaching to groundwater results at the five percent probability of exceedance level.

TABLE 3-15
CHLORSULFURON RESULTS, LANDMARK 2 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.05728	0.05937	0.037	0.309	0.000
10% Probability of Exceedance	0.03363	0.03927	0.020	0.227	0.000
25% Probability of Exceedance	0.01535	0.02363	0.006	0.171	0.000
50% Probability of Exceedance	0.00751	0.01404	0.002	0.104	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	12.82296	9.60208	11.653	57.130	0.000
10% Probability of Exceedance	5.83294	4.72023	4.925	25.033	0.000
25% Probability of Exceedance	3.88350	3.82337	2.715	21.261	0.000
50% Probability of Exceedance	2.31956	2.64113	1.129	16.287	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.11272	0.24053	0.041	2.235	0.000
10% Probability of Exceedance	0.09042	0.15239	0.027	1.348	0.000
25% Probability of Exceedance	0.05895	0.12297	0.015	0.719	0.000
50% Probability of Exceedance	0.04342	0.11699	0.006	0.749	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	4.20973	3.32292	3.208	22.570	0.000
10% Probability of Exceedance	2.09062	1.56429	1.860	15.648	0.000
25% Probability of Exceedance	1.71371	1.47686	1.610	14.799	0.000
50% Probability of Exceedance	1.23999	1.19167	1.169	9.251	0.000

Notes:
Application rate: 2 oz/acre Landmark
Chlorsulfuron: 0.0234 pound/acre, 26.252 gram/hectare, Application date: July 15

Source: Project Team

TABLE 3-16
CHLORSULFURON RESULTS, LANDMARK 1 OZ/ACRE RATE

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.02864	0.02968	0.019	0.155	0.000
10% Probability of Exceedance	0.01681	0.01963	0.010	0.114	0.000
25% Probability of Exceedance	0.00767	0.01182	0.003	0.086	0.000
50% Probability of Exceedance	0.00376	0.00702	0.001	0.052	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	6.41148	4.80104	5.827	28.565	0.000
10% Probability of Exceedance	2.91647	2.36011	2.463	12.517	0.000
25% Probability of Exceedance	1.94175	1.91168	1.358	10.631	0.000
50% Probability of Exceedance	1.15978	1.32057	0.565	8.144	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.05636	0.12027	0.021	1.118	0.000
10% Probability of Exceedance	0.04521	0.07620	0.014	0.674	0.000
25% Probability of Exceedance	0.02948	0.06148	0.008	0.360	0.000
50% Probability of Exceedance	0.02171	0.05849	0.003	0.375	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	2.10487	1.66146	1.604	11.285	0.000
10% Probability of Exceedance	1.04531	0.78214	0.930	7.824	0.000
25% Probability of Exceedance	0.85686	0.73843	0.805	7.400	0.000
50% Probability of Exceedance	0.61999	0.59584	0.585	4.626	0.000

Notes:
Application rate: 1 oz/acre Landmark
Chlorsulfuron: 0.0117 pound/acre, 13.126 gram/hectare, application date: July 15

Source: Project Team

3.3.9 Amino Pyralid

Amino pyralid is the active ingredient in a new chemical formulation, currently undergoing approval by the government agencies, called Dow Product DE 750 or Milestone VM. Only one application rate of this compound was modeled.

Table 3-17 contains the summary statistics of the NAPRA GLEAMS model output for amino pyralid. In general, amino pyralid tends to be present more in the percolated water than in the runoff water. **Exhibits I.1** and **I.2** depict the runoff results and leaching to groundwater results for amino pyralid at the five percent probability of exceedance level across the State of Texas.

TABLE 3-17
AMINO PYRALID RESULTS

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.01821	0.04690	0.002	0.586	0
10% Probability of Exceedance	0.00698	0.01779	0.001	0.231	0
25% Probability of Exceedance	0.00181	0.00430	0	0.043	0
50% Probability of Exceedance	0.00050	0.00127	0	0.011	0
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	9.76097	10.86599	5.683	66.451	0
10% Probability of Exceedance	6.14949	7.10919	3.606	43.715	0
25% Probability of Exceedance	2.50650	3.03911	1.377	22.634	0
50% Probability of Exceedance	0.83043	1.29515	0.274	9.896	0
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.01151	0.02300	0.004	0.2	0
10% Probability of Exceedance	0.00474	0.00767	0.002	0.08	0
25% Probability of Exceedance	0.00167	0.00282	0	0.021	0
50% Probability of Exceedance	0.00082	0.00159	0	0.009	0
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	2.68497	2.00854	2.193	12.947	0
10% Probability of Exceedance	1.98829	1.60859	1.48	10.643	0
25% Probability of Exceedance	1.05611	0.94229	0.856	6.6	0
50% Probability of Exceedance	0.38699	0.47339	0.22	3.438	0

Notes:
Application rate: 7 oz/acre Dow Product DE 750, Milestone VM
Amino pyralid: 0.1097 pound/acre, 123.07 gram/hectare, application date: April 30

Source: Project Team

3.3.10 Imazapyr

Imazapyr is the active ingredient in Habitat. Only one application rate of this compound was modeled. **Table 3-18** contains the summary statistics of the NAPRA GLEAMS model output for imazapyr. In general, imazapyr tends to be present more in the percolated water than in the runoff water. **Exhibits J.1** and **J.2** depict the runoff results and leaching to groundwater results for imazapyr at the five percent probability of exceedance level across the State of Texas.

TABLE 3-18
IMAZAPYR RESULTS

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	6.85667	9.69740	2.636	86.009	0.000
10% Probability of Exceedance	4.16088	6.22969	1.484	46.762	0.000
25% Probability of Exceedance	2.13953	3.47464	0.726	24.993	0.000
50% Probability of Exceedance	1.01946	1.80154	0.274	12.668	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	93.31268	128.41375	43.859	710.512	0.000
10% Probability of Exceedance	71.00027	103.12845	28.705	696.578	0.000
25% Probability of Exceedance	47.42074	78.13934	13.510	509.549	0.000
50% Probability of Exceedance	27.69011	50.68633	4.857	368.516	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	5.03435	4.68012	3.724	25.498	0.000
10% Probability of Exceedance	3.73587	3.19628	2.978	17.220	0.000
25% Probability of Exceedance	2.96106	2.59820	2.227	13.719	0.000
50% Probability of Exceedance	2.32339	2.64302	1.350	14.361	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	26.52787	31.29092	14.677	247.584	0.000
10% Probability of Exceedance	23.35050	30.08196	12.265	250.421	0.000
25% Probability of Exceedance	19.14047	29.27445	8.113	287.693	0.000
50% Probability of Exceedance	13.20276	23.07773	4.800	188.135	0.000

Notes:
Application rate: 2 quarts/acre Habitat
Imazapyr: 0.99 pound/acre, 1,110.66 gram/hectare, application date: May 1

Source: Project Team

3.3.11 Fenoxycarb

Fenoxycarb is the active ingredient in the Award brand of herbicide. Only one application rate of this compound was modeled. **Table 3-19** contains the summary statistics of the NAPRA GLEAMS model output for fenoxycarb. In general, fenoxycarb mass in either runoff or leaching water was found to be low due to the low application rate applied to the roadsides. **Exhibits K.1** and **K.2** depict the runoff results and leaching to groundwater results for fenoxycarb at the five percent probability of exceedance level across the State of Texas.

TABLE 3-19
FENOXYCARB RESULTS

Mass in Runoff and Leaching (g/ha)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.00449	0.00629	0.002	0.045	0.000
10% Probability of Exceedance	0.00084	0.00162	0.000	0.013	0.000
25% Probability of Exceedance	0.00003	0.00017	0.000	0.001	0.000
50% Probability of Exceedance	0.00000	0.00000	0.000	0.000	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.00056	0.00571	0.000	0.069	0.000
10% Probability of Exceedance	0.00000	0.00005	0.000	0.001	0.000
25% Probability of Exceedance	0.00000	0.00000	0.000	0.000	0.000
50% Probability of Exceedance	0.00000	0.00000	0.000	0.000	0.000
Concentrations in Runoff and Leaching (ppb)					
Runoff	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.00311	0.00440	0.001	0.028	0.000
10% Probability of Exceedance	0.00053	0.00094	0.000	0.004	0.000
25% Probability of Exceedance	0.00000	0.00003	0.000	0.001	0.000
50% Probability of Exceedance	0.00000	0.00000	0.000	0.000	0.000
Leaching	Average	SD	Median	Max	Min
5% Probability of Exceedance	0.00017	0.00189	0.000	0.023	0.000
10% Probability of Exceedance	0.00000	0.00000	0.000	0.000	0.000
25% Probability of Exceedance	0.00000	0.00000	0.000	0.000	0.000
50% Probability of Exceedance	0.00000	0.00000	0.000	0.000	0.000

Notes:
Application rate: 1 lb/acre Award
Fenoxycarb: 0.01 pound/acre, 11.22 gram/hectare, application date: April 30

Source: Project Team

3.4 COMPARISON OF CHEMICALS

Table 3-20 lists the chemicals ranked with respect to application rate. For comparative purposes, the five percent probability of exceedance values and the 50 percent probability of exceedance values were used. Using the five percent exceedance value provides a conservative scenario, while the 50 percent exceedance value provides a more realistic scenario.

TABLE 3-20
APPLICATION RATES RANKED BY MASS APPLIED

Active Ingredient	Trade Name	Formulation	lb/acre	g/ha	Rank
Glyphosate	Round up Pro & Aquamaster	liquid	3	3365.638	1
Imazapyr	Habitat & Arsenal	liquid	0.99	1110.661	2
Triclopyr	Garlon	liquid	0.75	841.410	3
Clopyralid	Transline	liquid	0.4925	552.526	4
Glyphosate	Round up Pro & Aquamaster	liquid	0.3735	419.022	5
Clopyralid	Transline	liquid	0.2345	263.081	6
Glyphosate	Round up Pro & Aquamaster	liquid	0.1875	210.352	7
Fluroxypyr	Vista	liquid	0.1174	131.709	8
Metsulfuron methyl	Escort XP	solid	0.1125	126.211	9
Amino pyralid	Dow Product DE 750, Milestone VM	liquid	0.1097	123.070	10
Sulfometuron methyl	Oust XP	solid	0.09375	105.176	11
Sulfometuron methyl	Landmark MP	solid	0.0703	78.868	12
Sulfosulfuron	Outrider	solid	0.0623	69.893	13
Metsulfuron methyl	Escort XP	solid	0.0375	42.070	14
Sulfometuron methyl	Landmark MP	solid	0.0352	39.490	15
Chlorsulfuron	Landmark MP	solid	0.0234	26.252	16
Chlorsulfuron	Landmark MP	solid	0.0117	13.126	17
Fenoxycarb	Award	solid	0.01	11.219	18

Source: Project Team

3.4.1 Runoff

Table 3-21 contains the ranking of the chemicals by runoff concentration at both the five percent probability of exceedance as well as the 50 percent probability of exceedance. Higher application rates typically yielded higher runoff concentrations. However, there were a few exceptions, including amino pyralid and clopyralid, both of which had higher application rates, but ranked near the bottom of the list in terms of runoff concentrations. There was very little difference in the rankings when the five percent levels are compared to the 50 percent levels.

Table 3-22 contains the mass of chemical in the runoff compared to the mass of chemical applied to the roadsides on a percentage basis, in order to evaluate how much of the chemical applied ends up in the runoff water. The data suggest that higher application rates do not always result in higher runoff concentrations. As the data indicate, some of the higher application rates have a lower percentage of mass in the runoff. This result seems to relate to the quantity of the chemical, which surfaces in the percolated water.

TABLE 3-21
RUNOFF CONCENTRATION COMPARISON

Active Ingredient	Trade Name	Application Rate	Average Runoff Concentration (ppb)
5% Probability of Exceedance, Ranked Highest to Lowest for Runoff Concentration			
Glyphosate	Round up Pro	4 quarts/acre	14.0500
Imazapyr	Habitat	2 quarts/acre	5.0343
Triclopyr	Garlon	1 quart/acre	2.0737
Glyphosate	Round up Pro	16 oz/acre	1.0426
Fluroxypyr	Vista	10 oz/acre	1.0234
Metsulfuron methyl	Escort XP	3 oz/acre	0.9823
Glyphosate	Round up Pro	8 oz/acre	0.5006
Metsulfuron methyl	Escort XP	1 oz/acre	0.3366
Sulfometuron methyl	Oust XP	2 oz/acre	0.1241
Chlorsulfuron	Landmark MP	2 oz/acre	0.1127
Sulfometuron methyl	Landmark MP	2 oz/acre	0.1029
Clopyralid	Transline	21 oz/acre	0.0833
Sulfosulfuron	Outrider	1.33 oz/acre	0.0697
Chlorsulfuron	Landmark MP	1 oz/acre	0.0564
Sulfometuron methyl	Landmark MP	1 oz/acre	0.0514
Amino pyralid	Dow Product DE 750	7 oz/acre	0.0115
Clopyralid	Transline	10 oz/acre	0.0072
Fenoxycarb	Award	1 lb/acre	0.0031
50% Probability of Exceedance, Ranked Highest to Lowest for Runoff Concentration			
Glyphosate	Round up Pro	4 quarts/acre	6.8287
Imazapyr	Habitat	2 quarts/acre	2.3234
Triclopyr	Garlon	1 quart/acre	0.7475
Glyphosate	Round up Pro	16 oz/acre	0.4078

TABLE 3-21
RUNOFF CONCENTRATION COMPARISON

Active Ingredient	Trade Name	Application Rate	Average Runoff Concentration (ppb)
Metsulfuron methyl	Escort XP	3 oz/acre	0.3436
Fluroxypyr	Vista	10 oz/acre	0.2575
Glyphosate	Round up Pro	8 oz/acre	0.2000
Metsulfuron methyl	Escort XP	1 oz/acre	0.1179
Chlorsulfuron	Landmark MP	2 oz/acre	0.0434
Sulfosulfuron	Outrider	1.33 oz/acre	0.0315
Sulfometuron methyl	Oust XP	2 oz/acre	0.0311
Sulfometuron methyl	Landmark MP	2 oz/acre	0.0224
Chlorsulfuron	Landmark MP	1 oz/acre	0.0217
Clopyralid	Transline	21 oz/acre	0.0190
Sulfometuron methyl	Landmark MP	1 oz/acre	0.0112
Amino pyralid	Dow Product DE 750	7 oz/acre	0.0008
Clopyralid	Transline	10 oz/acre	0.0001
Fenoxycarb	Award	1 lb/acre	0.0000

Source: Project Team

TABLE 3-22
MASS IN RUNOFF PERCENTAGE

Active Ingredient	Trade Name	Application Rate (g/ha)	Mass in Runoff (g/ha)	% of Applied Mass
5% Probability of Exceedance, Ranked Highest to Lowest for % Applied Mass in Runoff				
Fluroxypyr	Vista	131.709	1.60517	1.22
Imazapyr	Habitat	1110.661	6.85667	0.62
Glyphosate	Round up Pro	3365.638	16.58225	0.49
Metsulfuron methyl	Escort XP	42.070	0.17224	0.41
Metsulfuron methyl	Escort XP	126.211	0.50128	0.40
Glyphosate	Round up Pro	419.022	1.48558	0.35
Glyphosate	Round up Pro	210.352	0.62634	0.30
Chlorsulfuron	Landmark MP	26.252	0.05728	0.22
Chlorsulfuron	Landmark MP	13.126	0.02864	0.22
Sulfometuron methyl	Oust XP	105.176	0.19576	0.19
Sulfometuron methyl	Landmark MP	78.868	0.13727	0.17
Sulfometuron methyl	Landmark MP	39.490	0.06864	0.17
Sulfosulfuron	Outrider	69.893	0.09161	0.13

TABLE 3-22
MASS IN RUNOFF PERCENTAGE

Active Ingredient	Trade Name	Application Rate (g/ha)	Mass in Runoff (g/ha)	% of Applied Mass
Triclopyr	Garlon	841.410	0.89827	0.11
Fenoxycarb	Award	11.219	0.00449	0.04
Amino pyralid	Dow Product DE 750	123.070	0.01821	0.01
Clopyralid	Transline	552.526	0.04751	0.01
Clopyralid	Transline	263.081	0.01350	0.01
50% Probability of Exceedance, Ranked Highest to Lowest for % Applied Mass in Runoff				
Fluroxypyr	Vista	131.709	0.15542	0.12
Imazapyr	Habitat	1110.661	1.01946	0.09
Glyphosate	Round up Pro	3365.638	2.98555	0.09
Glyphosate	Round up Pro	419.022	0.21686	0.05
Glyphosate	Round up Pro	210.352	0.08775	0.04
Metsulfuron methyl	Escort XP	126.211	0.05071	0.04
Metsulfuron methyl	Escort XP	42.070	0.01683	0.04
Chlorsulfuron	Landmark MP	13.126	0.00376	0.03
Chlorsulfuron	Landmark MP	26.252	0.00751	0.03
Sulfosulfuron	Outrider	69.893	0.01260	0.02
Sulfometuron methyl	Oust XP	105.176	0.01811	0.02
Sulfometuron methyl	Landmark MP	78.868	0.01322	0.02
Sulfometuron methyl	Landmark MP	39.490	0.00661	0.02
Triclopyr	Garlon	841.410	0.09521	0.01
Clopyralid	Transline	552.526	0.00272	0.00
Amino pyralid	Dow Product DE 750	123.070	0.00050	0.00
Clopyralid	Transline	263.081	0.00009	0.00
Fenoxycarb	Award	11.219	0.00000	0.00

Source: Project Team

3.4.2 Leaching to Groundwater

Table 3-23 ranks the chemicals according to leaching concentrations at the five and 50 percent probability of exceedance levels. The model predicts that much higher concentrations of chemicals would occur in the water at the bottom of the root zone than in runoff. The model suggests that the application of glyphosate is unlikely to leach to groundwater. This is likely attributable to this chemical's strong affinity to bind to organic carbon in the soil.

Table 3-24 provides the percentage of chemical mass from the application, which enters into percolated water. In general, these rankings are not substantially different from the ones in **Table 3-23**. The same properties of the chemicals affect the amount of chemical that ends up percolating through the root zone, specifically K_{oc} values and soil half-lives.

TABLE 3-23
CONCENTRATION IN LEACHING COMPARISON

Active Ingredient	Trade Name	Application Rate	Average Leaching Concentration (ppb)
5% Probability of Exceedance, Ranked Highest to Lowest for Concentration in Leaching			
Triclopyr	Garlon	1 quart/acre	83.41059
Imazapyr	Habitat	2 quarts/acre	26.52787
Clopyralid	Transline	21 oz/acre	14.30337
Metsulfuron methyl	Escort XP	3 oz/acre	9.51985
Glyphosate	Round up Pro	4 quarts/acre	6.99850
Chlorsulfuron	Landmark MP	2 oz/acre	4.20973
Metsulfuron methyl	Escort XP	1 oz/acre	3.33873
Clopyralid	Transline	10 oz/acre	3.00276
Amino pyralid	Dow Product DE 750	7 oz/acre	2.68497
Chlorsulfuron	Landmark MP	1 oz/acre	2.10487
Sulfosulfuron	Outrider	1.33 oz/acre	1.55247
Fluroxypyr	Vista	10 oz/acre	0.47732
Sulfometuron methyl	Oust XP	2 oz/acre	0.28879
Glyphosate	Round up Pro	16 oz/acre	0.24527
Glyphosate	Round up Pro	8 oz/acre	0.23395
Sulfometuron methyl	Landmark MP	2 oz/acre	0.22422
Sulfometuron methyl	Landmark MP	1 oz/acre	0.11211
Fenoxycarb	Award	1 lb/acre	0.00017
50% Probability of Exceedance, Ranked Highest to Lowest for Concentration in Leaching			
Triclopyr	Garlon	1 quart/acre	48.63674
Imazapyr	Habitat	2 quarts/acre	13.20276
Metsulfuron methyl	Escort XP	3 oz/acre	4.85169
Glyphosate	Round up Pro	4 quarts/acre	3.50903
Clopyralid	Transline	21 oz/acre	3.25971
Metsulfuron methyl	Escort XP	1 oz/acre	1.51252

TABLE 3-23
CONCENTRATION IN LEACHING COMPARISON

Active Ingredient	Trade Name	Application Rate	Average Leaching Concentration (ppb)
Chlorsulfuron	Landmark MP	2 oz/acre	1.23999
Chlorsulfuron	Landmark MP	1 oz/acre	0.61999
Sulfosulfuron	Outrider	1.33 oz/acre	0.38795
Amino pyralid	Dow Product DE 750	7 oz/acre	0.38699
Clopyralid	Transline	10 oz/acre	0.13360
Fluroxypyr	Vista	10 oz/acre	0.09169
Glyphosate	Round up Pro	16 oz/acre	0.09110
Glyphosate	Round up Pro	8 oz/acre	0.08684
Sulfometuron methyl	Oust XP	2 oz/acre	0.02445
Sulfometuron methyl	Landmark MP	2 oz/acre	0.01563
Sulfometuron methyl	Landmark MP	1 oz/acre	0.00781
Fenoxycarb	Award	1 lb/acre	0.00000

Source: Project Team

TABLE 3-24
MASS IN LEACHING PERCENTAGES

Active Ingredient	Trade Name	Application Rate (g/ha)	Mass in Leaching (g/ha)	% of Applied Mass
5% Probability of Exceedance, Ranked Highest to Lowest for Applied Mass % in Leaching				
Chlorsulfuron	Landmark MP	26.252	12.82296	48.85
Chlorsulfuron	Landmark MP	13.126	6.41148	48.85
Triclopyr	Garlon	841.410	265.0012	31.49
Metsulfuron methyl	Escort XP	42.070	11.9226	28.34
Metsulfuron methyl	Escort XP	126.211	34.4897	27.33
Imazapyr	Habitat	1110.661	93.3127	8.40
Amino pyralid	Dow Product DE 750	123.070	9.76097	7.93
Clopyralid	Transline	552.526	43.7296	7.91
Sulfosulfuron	Outrider	69.893	4.63186	6.63
Clopyralid	Transline	263.081	11.8533	4.51
Fluroxypyr	Vista	131.709	1.5322	1.16
Sulfometuron methyl	Oust XP	105.176	0.8117	0.77
Sulfometuron methyl	Landmark MP	78.868	0.56015	0.71
Sulfometuron methyl	Landmark MP	39.490	0.28007	0.71
Glyphosate	Round up Pro	3365.638	13.6266	0.40

TABLE 3-24
MASS IN LEACHING PERCENTAGES

Active Ingredient	Trade Name	Application Rate (g/ha)	Mass in Leaching (g/ha)	% of Applied Mass
Glyphosate	Round up Pro	210.352	0.54442	0.26
Glyphosate	Round up Pro	419.022	0.7013	0.17
Fenoxycarb	Award	11.219	0.0006	0.00
50% Probability of Exceedance, Ranked Highest to Lowest for Applied Mass in Leaching				
Triclopyr	Garlon	841.410	85.9273	10.21
Chlorsulfuron	Landmark MP	26.252	2.31956	8.84
Chlorsulfuron	Landmark MP	13.126	1.15978	8.84
Metsulfuron methyl	Escort XP	126.211	10.4351	8.27
Metsulfuron methyl	Escort XP	42.070	3.3460	7.95
Imazapyr	Habitat	1110.661	27.6901	2.49
Clopyralid	Transline	552.526	6.9956	1.27
Sulfosulfuron	Outrider	69.893	0.81938	1.17
Amino pyralid	Dow Product DE 750	123.070	0.83043	0.67
Clopyralid	Transline	263.081	0.3413	0.13
Fluroxypyr	Vista	131.709	0.1393	0.11
Glyphosate	Round up Pro	3365.638	3.0890	0.09
Sulfometuron methyl	Oust XP	105.176	0.0476	0.05
Sulfometuron methyl	Landmark MP	78.868	0.02910	0.04
Sulfometuron methyl	Landmark MP	39.490	0.01455	0.04
Glyphosate	Round up Pro	210.352	0.06951	0.03
Glyphosate	Round up Pro	419.022	0.0935	0.02
Fenoxycarb	Award	11.219	0.0000	0.00

Source: Project Team

3.4.3 Site Specific Comparison

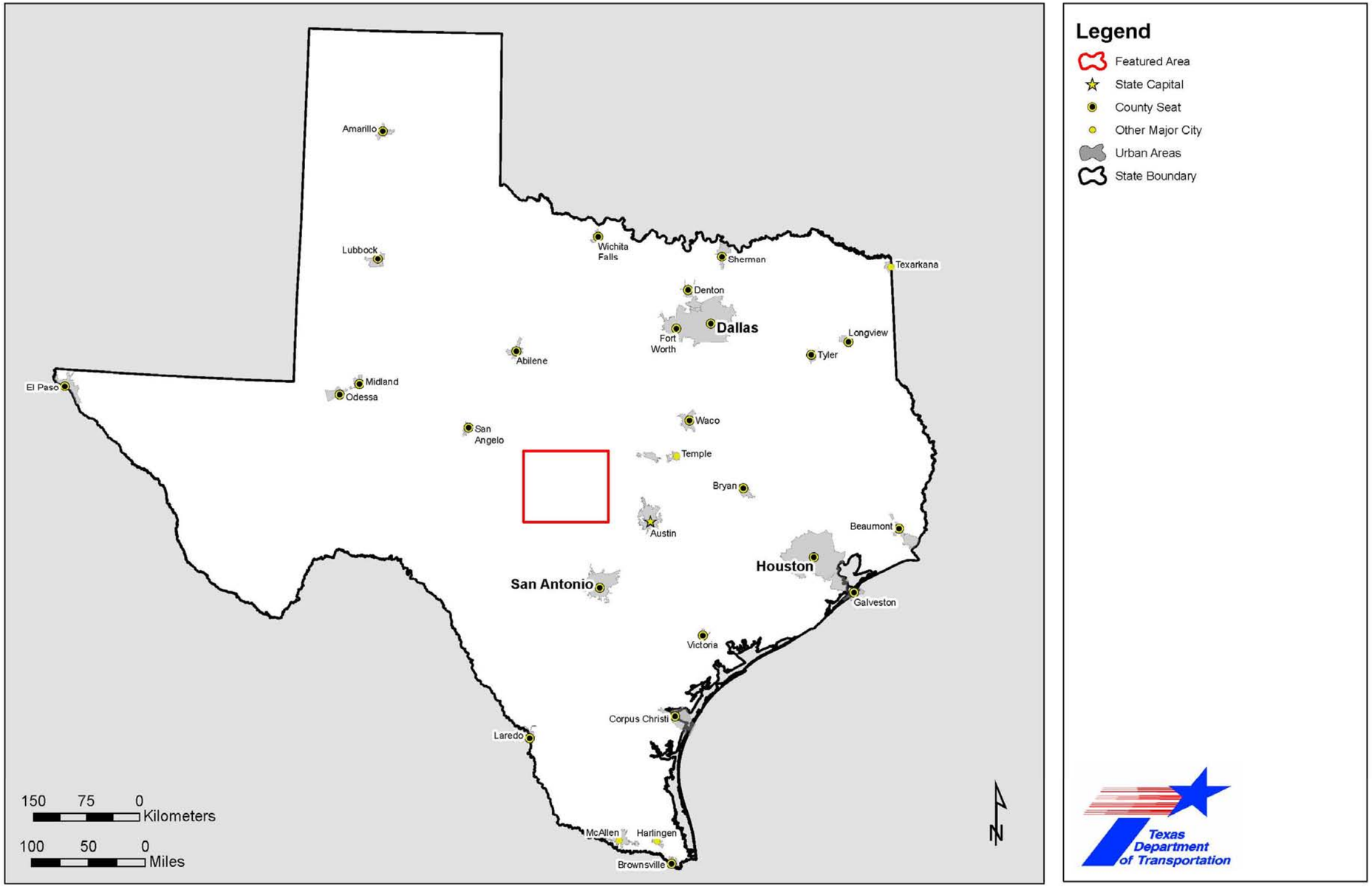
The data generated through this effort provide a quantitative tool for TxDOT's roadside pest managers to use in management decisions involving the application of chemicals within the ROW. **Figure 3-3** depicts a localized area in which several site-specific comparisons can be made between runoff and leaching potential of various chemicals. This location provides a good area for comparison since it contains a variety of soil types and is near a large surface water body, Lake Buchanan. The following paragraphs discuss specific comparisons for this area. Using the results of this effort, similar comparisons can be made anywhere else in the State of Texas.

Figures 3-4 through **3-39** (located at the end of the report) provide maps of this localized area for some of the outputs generated by the model. These figures contain runoff and leaching concentrations for various chemicals and application rates at the 5 percent probability of exceedance result (i.e., 95 percent of the chemical concentrations modeled occur within or below the reported range).

The results of this effort indicate that the average mass of a particular chemical in runoff is typically greater than the average mass of the same chemical in percolating water (see **Tables 3-2**, **3-3**, and **3-4**). However, in some cases, concentrations at the bottom of the root zone resulting from leaching are sometimes greater then concentrations associated with the same chemical in runoff (see **Figures 3-4** and **3-22**). A good example of this is along U.S. Highway Route 87 (US 87) in the area underlying the southernmost US 87 symbol on **Figures 3-4** and **3-22**. In this particular area, the modeled runoff concentrations of glyphosate range from 0.220 to 0.437 ppb (**Figure 3-4**) while the modeled leaching concentrations are higher ranging from 0.607 to 1.816 ppb (**Figure 3-22**) in the same area. For this particular area, infiltration via leaching poses a greater risk to water quality than that of runoff associated with glyphosate application.

In some cases, two different chemicals can be used to treat the same pest species. For example, Transline (active ingredient clopyralid) and Garlon 3a (active ingredient triclopyr) can be used to manage huisache (*Acacia smallii*) and retama (*Parkinsonia aculeate*). **Figures 3-14** and **3-16** provide the runoff concentrations for each of these active ingredients at the maximum application rates used by TxDOT. Concentrations in runoff by specific geographic location can be determined for each of these chemicals. For example, just southwest of the US 377/US 87 intersection, the model predicts a runoff concentration for clopyralid of 0.064 ppb to 0.198 ppb and a runoff concentration of triclopyr of 0.000 ppb to 1.903 ppb for this area. Given the lower runoff concentrations associated with clopyralid, using clopyralid would minimize the risks to water quality associated with runoff at this location. This would also minimize the potential for adverse effects to ecological receptors. The other figures in this section provide a detailed view of several other chemicals at this same specific location, which allows similar comparisons on a more localized scale.

FIGURE 3-3
TEXAS OVERVIEW



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3.5 MODEL UNCERTAINTY AND ASSUMPTIONS

This section identifies key assumptions and sources of uncertainty associated with the water quality runoff modeling effort. The model yielded runoff and leaching results for the entire State of Texas, i.e., chemistry and application rates, were assumed to be equal regardless of the specific geographic location within the state. This serves as a source of uncertainty since different chemicals are used for different vegetation growing in different parts of the state.

The model considered all soils series within the State of Texas and the corresponding properties of those soils. TxDOT's ROW typically consists of disturbed soils resulting from cut and fill operations required for initial construction. Therefore, some uncertainty exists regarding soil properties modeled versus the properties of soils located within the TxDOT ROW on which the Pest Management Program applies.

During model simulations, the application date of each chemical was assumed to be the same for each year over the 60-year time period analyzed. Chemical application dates vary depending on localized precipitation, weather trends, and atmospheric conditions.

One application of each chemical per year was used for modeling purposes. In some cases, TxDOT applies chemicals more than one time per year.

The model assumes broadcast spray as the method of application for all of the chemicals evaluated. Assuming this application method for all chemicals results in the most mass of chemical applied to the plants and soils. Therefore, this approach serves as a measure of conservatism in terms of runoff and leaching concentration results. Other application methods may be used, but would likely result in less mass of a given chemical in runoff or percolation water.

The timing of the chemical application and the rainfall generation portions of the model function independently of one another. This means that from the model's perspective a chemical is applied just prior to a precipitation event. According to TxDOT's Herbicide Operations Manual (TxDOT, 2004), "herbicides should not be applied when rainfall is threatening or is imminent." Since chemical applications just prior to a precipitation event contradicts TxDOT policy, this model assumption serves as another source of conservatism.

In the leaching scenario, the resulting concentrations apply to the area within the soil profile located at the bottom of the root zone. Actual concentrations of a particular chemical reaching groundwater may be substantially lower due to further biodegradation and/or adsorption of the chemicals in the soils below the root zone but above the groundwater.

Similarly, the model results do not consider further degradation of chemicals in runoff water that could occur prior to that runoff water reaching a surface water body. The model results provide concentrations applicable to a theoretical "edge of the field" (i.e., edge of the ROW.

4.0 SUMMARY AND CONCLUSIONS

The purpose of this water quality modeling effort was to assess the runoff potential of several chemicals currently in use or proposed for use on TxDOT's ROW. The results of this effort provide TxDOT maintenance personnel with a quantitative tool for assessing potential risks associated with runoff or percolation from the ROW. Using the data contained in this report allow the comparison of the runoff and leaching potential of each chemical by geographic location within the State of Texas.

In order to provide a frame of reference for the model results, comparisons can be made to established regulatory thresholds. Glyphosate is the only chemical used or planned for use in TxDOT's program with a water quality regulatory standard. The EPA established a Maximum Contaminant Level (MCL) of 0.7 mg/L (700 ppb) for glyphosate. EPA defines an MCL as the highest level of a contaminant that is allowed in drinking water.

EPA also established a Maximum Contaminant Level Goal (MCLG) of 0.7 mg/L (700 ppb) for glyphosate. EPA defines an MCLG as the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration.

The Texas Council on Environmental Quality's (TCEQ) Drinking Water Standards Governing Drinking Water Quality and Reporting Requirements for Public Water Supply Systems (30 TAC Chapter 290 Subchapter F) use the federal MCL standard (0.7 mg/L [700 ppb]) for glyphosate. Based on the results of the model, the maximum concentration of glyphosate in runoff and percolation water would be 14 ppb and 3.5 ppb, respectively. Even with the conservative assumptions used in the modeling, the resulting concentrations of glyphosate due to TxDOT's maintenance program are still one to two orders of magnitude below the standards established by EPA and adopted by TCEQ below which there is no known or expected risk to human health.

As TxDOT's Herbicide Operations Manual (TxDOT, 2004) suggests, the proper selection of herbicides and proper application rates are dependent upon the type and species of vegetation to be controlled, as well as the condition of the plant species itself. As part of its integrated pest management (IPM) approach, TxDOT applies chemicals

to the ROW with environmental considerations in mind and strives to use the least amount of chemicals necessary to achieve desired results. As a result, managing the quality of the water leaving the ROW via runoff or percolation is an important consideration for the Department.

Consequently, many of the risk management decisions occurring in TxDOT's Pest Management Program rely on qualitative and site-specific considerations. This report and the resulting GIS provide TxDOT with a new, quantitative risk management tool particularly useful for managing potential risks associated with pesticides in ROW runoff and percolating water beneath the ROW on a regional basis. When used in conjunction with site-specific and qualitative considerations, this tool will enhance TxDOT's ability to make environmentally sensitive decisions regarding the use of pesticides throughout the State of Texas.

5.0 REFERENCES

Engel, B. and Lee, J. (2000). Retrieved from http://wcca.ifas.ufl.edu/archive/7thProc/ENGEL/ENGEL.htm.

Knisel, W.G. and Davis, F.M. (2000). *GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), Version 3.0, User Manual.* U.S. Department of Agriculture, Agricultural Research Service, Southeast Watershed Research Laboratory, Tifton, GA. Pub. No.: SEWRL-WGK/FMD-050199. Report Dated May 1, 1999 and revised August 15, 2000. 194 pp.

Lim, K.J. and Engel, B.A. (2003). Extension and Enhancement of National Agricultural Pesticide Risk Analysis (NAPRA) WWW Decision Support System to Include Nutrients. *Computers and Electronics in Agriculture* 38, 227-236.

Leonard, R.A., Davis, F.M., and Knisel, W.G. (2002). Retrieved from http://www.wiz.uni-kassel.de/model_db/mdb/gleams.html.

National Resource Conservation Service (NRCS) (2001). *Contents, Part 404, Pest Management*. 190-GM, Amendment 5, November 2001.

Texas Department of Transportation. (2004). *Herbicide Operations Manual*. Austin.

United States Department of Agriculture (USDA). (2005). Retrieved June 15, 2005 from: http://horizon.nserl.purdue.edu/Cligen/

http://dbwww.essc.psu.edu/dbtop/amer_n/us_sc/tx/data/soilprop/statsgo/doc.html

http://wcca.ifas.ufl.edu/archive/7thProc/ENGEL/ENGEL.htm

(http://www.wiz.uni-kassel.de/model_db/mdb/gleams.html http://www3.bae.ncsu.eud/Regional-Bulletins/Modeling-Bulletin/ASCE99-gleams-draft.html

http://www.ped.muni.cz/wgeo/staff/svatonova/AGNPS/Elsevier_PDF/12.pdf.

USDA-ARS Southeast Watershed Research Laboratory. (2004). Retrieved from http://www.cpes.peachnet.edu/sewrl/Gleams/gleams_y2k_update.htm.

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